U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB80-148000

# Minisite Preparation for Reforestation of Strip-Mined Lands

Tennessee Univ, Knoxville

Prepared for

Industrial Environmental Research Lab -Cincinnati, OH

Jan 80

USDA

United States
Department of
Agriculture

Cooperative
Research
Washington DC 20250

PB80-148000

EPA

United States
Environmental Protection
Agency

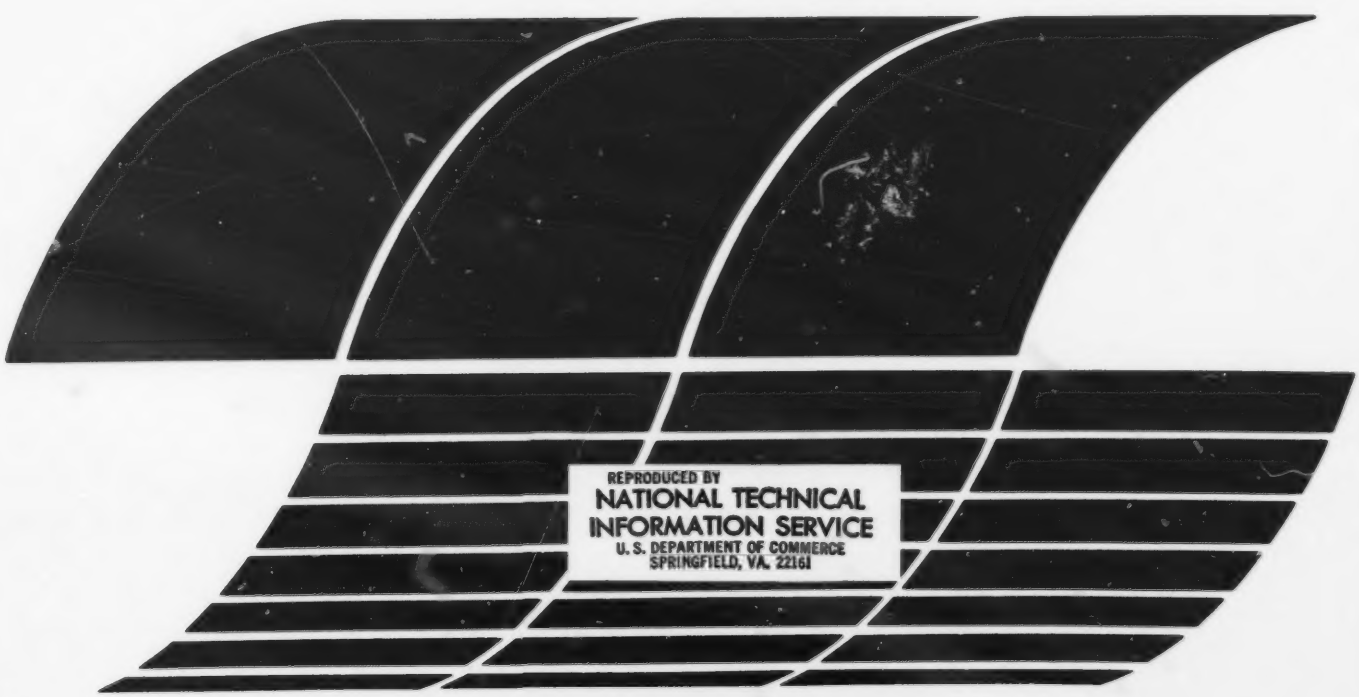
Industrial Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/7-80-005
January 1980

Research and Development

# Minisite Preparation for Reforestation of Strip-Mined Lands

## Interagency Energy/Environment R&D Program Report



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

## RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the INTERAGENCY ENERGY-ENVIRONMENT RESEARCH AND DEVELOPMENT series. Reports in this series result from the effort funded under the 17-agency Federal Energy/Environment Research and Development Program. These studies relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the Program is to assure the rapid development of domestic energy supplies in an environmentally-compatible manner by providing the necessary environmental data and control technology. Investigations include analyses of the transport of energy-related pollutants and their health and ecological effects; assessments of, and development of, control technologies for energy systems; and integrated assessments of a wide range of energy-related environmental issues.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA-600/7-80-005 | | PB 80 148000 |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Minisite Preparation for Reforestation of Strip-Mined Lands | January 1980 issuing date |
| | 6. PERFORMING ORGANIZATION CODE |

| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
|---|---|
| Ronald L. Hay<br>Frank W. Woods | CR-9 |

| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
|---|---|
| Department of Forestry, Wildlife, and Fisheries<br>University of Tennessee<br>P. O. Box 1071<br>Knoxville, TN 37901 | INE 623 |
| | 11. CONTRACT/GRANT NO.<br>EPA/IAG D6-E762<br>684-15-24 |

| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
|---|---|
| Industrial Environmental Research Laboratory<br>Office of Research and Development<br>U. S. Environmental Portection Agency<br>Cincinnati, Ohio 45268 | Final |
| | 14. SPONSORING AGENCY CODE<br>EPA/600/12 |

15. SUPPLEMENTARY NOTES
This project is part of the EPA-planned and coordinated Federal Interagency Energy/Environmental R&D Program

16. ABSTRACT

The purpose of this work was to test the hypothesis that site preparation of a minisite (20x60) cm cylinder) would be effective in promoting seedling survival and growth and still save considerable cost compared to area-wide site preparation. Spoil within the cylinder was mixed with organic matter, lime, and fertilizers, returned to the hole and rootrainer-grown tubeling planted. Controls were planted with a planting bar. The rootrainer medium was inoculated with Pisolithus tinctorius spores. All outplanted seedlings were irrigated once; planting was done June 29 and 30, 1977.

At the end of the first growing season, survival on minisite plots was 98% on bare areas and 86-90% on grassed areas. After the second season, 10% more trees died on the prepared bare areas. Survival on the grassed controls was 50% or less. Growth of pitch pine responded to minisite preparation on the grassed area but Virginia pine could not compete succeesfully with the grass. Both did equally well on the bare areas. Prescene of Pisolithus mycorrhizae on tubeling roots was found to be extremely important. Spoil amelioration is important, expecially when mycorrhizae are there to assist the plant in it utilication. Strip-mine spoil was successfully revegetated with pine by planting in mid-summer. Second year growth was better than the first year growth.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Ecology<br>Environment<br>Trees<br>Coal<br>Mine Reclamation<br>Stripmines<br>Reclamation | Pine<br>Spoil<br>Tennessee<br>Ecological Effects | 2A, 2D, 6M, 8H, 8M. |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
|---|---|---|
| Release unlimited | Unclassified | |
| | 20. SECURITY CLASS *(This page)*<br>Unclassified | 22. PRICE |


• U.S. GOVERNMENT PRINTING OFFICE 1980 -657-146/5537

EPA-600/7-80-005
January 1980

# MINISITE PREPARATION FOR REFORESTATION OF STRIP-MINED LANDS

by

Ronald L. Hay and Frank W. Woods
Department of Forestry, Wildlife, and Fisheries
The University of Tennessee
Knoxville, TN 37901

EPA/IAG D6-E762
SEA/CR No. 684-15-1

Program Coodinator

Eilif V. Miller
Mineland Reclamation Research Program
Science and Education Administration - Cooperative Research
U. S. Department of Agriculture
Washington, DC 20250

Project Officer
Ronald D. Hill
Resource Extraction and Handling Division
Industrial Environmental Research Laboratory - Cincinnati
Cincinnati, Ohio 45268

This study was conducted in cooperation with the Science and Education Administration, Cooperative Research U.S.D.A., Washington, D.C. 20250

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

## DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The views and conclusions contained in this report are those of the authors and should not be interpreted as representing the official policies or recommendations ot the Science and Education Administration-Cooperative Research, U. S. Department of Agriculture.

## FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes a minisite preparation method for planting trees on reclaimed surface mine. The benefits of this method is higher survival rates and potentially lower cost. Results of this study should be of interest to those charged with reclaiming surface mined lands. For further information contact the author or the Extraction Technology Branch of the Resource Extraction and Handling Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

## PREFACE

The problems facing an industrialized nation are numerous. One basic requirement for expansion is energy. Many hydroelectric and steam generating plants were established by 1945, but it was apparent even then that greater amounts of energy would soon be needed. Now with nuclear-powered generating plants on-line, our energy demands are still increasing at unprecedented rates.

Coal continues to be a significant energy source for electricity production. It has been estimated that our nation's internal coal supply will not be depleted within the next several hundred years. Coal mining will continue to be necessary for the maintenance of our present standard of living, since we rely heavily upon coal-derived energy and associated products. In this light, strip-mining is economically feasible and inevitable. Unfortunately, with this type of mining comes the initial destruction of natural habitats, stream and lake pollution, endangerment of wildlife, and deterioration of the aesthetic environment.

After mining operations, the soil material is a heterogeneous mass with physical and chemical properties dominated by the character of the geologic strata which overlaid the coal. In Tennessee, this includes surface soil, sands, shales, limestone, and sandstone. The methods of mining, using the various types of mining equipment, will also affect the resultant character of the mined area.

The potential productivity of the soil material left after mining is largely determined by its acidity and texture. In general, the higher the percentage of surface soil, sands and soft shales--the principal sources of soil particles 2 mm and less in size or texture--the greater are the opportunities for successful reclamation with agronomic and/or forest plants. Since 1945, approximately 4 million acres of land have been strip-mined, of which only 2 million have been revegetated.

Various actions can mitigate the undesirable effects of surface mining on the environment. They include the use of appropriate mining techniques, provision for adequate supervision, making plans for mining which are consistent and compatible with the uses of other resources, planning how much coal can be removed, and adequate rehabilitation of disturbed areas. This last item is our current concern.

Strip-mined areas are not natural "ecosystems," and there are few bases for establishing performance standards for operators once their mining operations are completed. The thrust of the work reported here will provide guidelines for operators reclaiming the multiplicity of spoil-types after mining has been completed.

ABSTRACT

The purpose of this work was to test the hypothesis that preparation of a minisite (20 x 60 cm cylinder) would be effective in promoting seedling survival and growth and still save considerable cost compared to area-wide site preparation. Spoil within the cylinder was mixed with organic matter, lime, and fertilizers, returned to the hole, and a rootrainer-grown pine was planted. Controls were planted with a planting bar. The rootrainer medium was inoculated with Pisolithus tinctorius spores. All outplanted seedlings were irrigated once; planting was done June 29 and 30, 1977.

At the end of the first growing season, survival on minisite plots was 98 percent on bare areas and 86-90 percent on grassed areas. After the second season, 10 percent more trees died on the prepared bare areas. Survival on the grassed controls was 50 percent or less. Pitch pine growth responded to minisite preparation on the grassed area but Virginia pine could not compete successfully with the grass. Both did equally well on the bare areas.

Presence of Pisolithus mycorrhizae on tubeling roots was found to be extremely important. Spoil amelioration was important, especially when mycorrhizae were there to assist the plant in their utilization.

Strip-mine spoil was successfully revegetated with pine by planting in mid-summer.

CONTENTS

Preface. . . . . iv
Abstract. . . . . vi
Tables. . . . . viii
Acknowledgment. . . . . ix

1. Introduction. . . . . 1
2. Conclusions . . . . . 3
3. Recommendations . . . . . 5
4. Experimental Procedures . . . . . 6
   General procedures . . . . . 6
   Experimental results . . . . . 11
   Discussion . . . . . 18

Appendices

A. Minisite Preparation for Reforestation of Strip-Mined Lands
B. Summer Planting on Strip Mines Successful
C. Tree Planting on Strip Mines - A Test of Minisite Preparation

TABLES


| Number | | Page |
|---|---|---|
| 1 | Virginia and Pitch Pines Outplanted on Minisite Preparation Study on Massingale Mountain, Campbell Cty, TN June 22 - July 5, 1977. . . . . | 8 |
| 2 | Pitch and Virginia Pine Survival Following June Outplanting of Pisolithus tinctorius Inoculated Seedlings on Strip-Mined Lands in Campbell Cty, TN . . . . . | 12 |
| 3 | Growth of Pitch and Virginia Pines Inoculated With Pisolithus tinctorius After Two Growing Seasons on Reclaimed Strip-Mine Spoil in Campbell Cty, TN . . . . . | 16 |

## ACKNOWLEDGMENTS

The authors wish to thank Dr. Eilif V. Miller of the Science and Education Administration, U.S. Department of Agriculture for his patience, support, and encouragement in the conduction of this work.

Dr. D. M. Gossett, Dean, Tennessee Agriculture Experiment Station, University of Tennessee coordinated the study and administered the project.

Grateful acknowledgment is also made to Tennessee Valley Authority, Department of Natural Resources, Norris, Tennessee and to Long Pit Mining Co., Caryville, Tennessee for coordinating the field logistics and being so helpful during spoil reclamation, site preparation, and outplanting.

# SECTION 1
# INTRODUCTION

The minisite preparation concept of this study was to intensively prepare a small site in which seedlings were planted. Preparation consisted of:

(1) excavation of soil in a 20 x 60 cm cylinder,

(2) removal of larger rocks by screening,

(3) mixing the excavated soil thoroughly,

(4) adding and mixing lime to neutralize active and reserve acidity,

(5) adding and mixing prescribed minerals to bring the soil into a well-balanced fertility for plant growth,

(6) adding and mixing organic matter as sewage sludge and pine bark chips,

(7) replacing the "renewed" soil in the cylinder from which it was excavated,

(8) planting a "tubeling" inoculated with an ectomycorrhizal fungus, and

(9) irrigating the seedling once.

The benefits obtained as a result of minisite preparation research outlined in this project are several, all of which relate to an increase in planting success following mining operations.

Survival on strip-mined areas may range from 0 to 90+ percent. Mine sites are frequently planted from 2 to 4 times before fulfilling the letter

of the law as regards tree stocking. This means that the spoils may be unprotected from driving rain and wind for up to 8 years before they enjoy a near-complete canopy cover. We believe that planters can consistently obtain 90 percent success using the minisite preparation approach, which would significantly decrease sedimentation and runoff following mining. Even though the initial cost of planting will be greater using mini-site preparation, the total cost to society will be less, because the public will ultimately pay for the repeated plantings which are necessary using current technology.

Direct users of the newly developed technology will be the sub-contractors who accept contractual responsibility for planting trees on strip mines following hydroseeding. While we encountered problems from frost-heaving of the newly planted tubelings on prepared minisites, it remains highly likely that the planting season can be extended from three to perhaps nine months. Planting should be possible in all but the most droughty periods.

Of great importance is the fact that a relatively small proportion of the total mined area must be site prepared. If a soil area of 314 $cm^2$ must be prepared for each of 1500 trees per hectare, only 0.5 percent of the area is managed, a notable savings over past practices in which entire site has been prepared. This should have considerable impact on projects that must be admitted to fiscal scrutiny. Clearly, the minisite preparation technique has the potential to have a substantial impact on the costs of strip-mining to society.

## SECTION 2

## CONCLUSIONS

A. Minisite preparation increased survival of pitch and Virginia pines on non-grassed and grassed areas after two years.

   1. On the non-grassed area, pine seedlings planted in prepared minisites had greater survival (5%) than pine seedlings planted without site preparation.
   2. On the grassed area, nearly twice the number of seedlings were alive on the prepared site as on the control site, regardless of species.
   3. Frost-heaving on the non-grassed site was not a problem for seedlings planted in prepared minisites, but 70 percent of the controls frost-heaved.

B. Summer planting was successful.

   1. Planting through July 4 was not detrimental to seedling survival as measured in the autumn and the following spring.
   2. Irrigation was used once, immediately following outplanting.

C. Growth of pitch and Virginia pines was affected by minisite preparation and competiting vegetation.

   1. Virginia pine growth was influenced by competiting vegetation, but not minisite preparation; tallest trees were on the non-grassed areas.

2. Pitch pine growth was helped by minisite preparation on both the grassed and non-grassed areas.

3. Virginia pine was the taller of the two species on either site.

D. Pisolithus tinctorius mycorrhizae appeared to be a useful adaptation for seedling survival and growth.

1. Seedling growth response variability was too high to be explained by treatment differences, but the success of Pisolithus inoculation was quite variable.

2. Seedling growth was apparently influenced by Pisolithus mycorrhizae, perhaps more so than by the experimental treatments.

3. A technique to assure more uniform inoculation success with Pisolithus mycorrhizae is required.

## SECTION 3

## RECOMMENDATIONS

1. Minisite preparation is helpful for pitch pine growth but Virginia pine was not similarly influenced. Virginia pine is more of a pioneer species than pitch pine on reclaimed coal spoil and should be used more frequently.
2. Minisite preparation is recommended not only to assist growth but also to minimize frost heaving problems which have become more severe each year.
3. Summer planting is possible, with irrigation at least once helpful. Planting season has been extended substantially and it may be possible to plant beyond July 4. Minisite preparation is critical to provide for good root growth medium and seedling anchoring.
4. Any pine seedling destined for outplanting on reclaimed coal spoil should be thoroughly inoculated with *Pisolithus tinctorius* mycorrhizae. Inoculum, commercially available from Abbott Labs, can be applied to nursery beds or to tubeling culture techniques. There is no reason to outplant any pine species without first equipping its root system with *Pisolithus*.

## SECTION 4

## EXPERIMENTAL PROCEDURES

### GENERAL PROCEDURES

The experimental areas chosen for this minisite preparation research were selected from Koppers Co. lands which were being mined by Long Pit Mining Co. under contract from the Tennessee Valley Authority (TVA). The sites were in the Cumberland Mountains near Caryville, Tennessee, about 35 miles north of Knoxville. The Pleasant Garden Ridge site on Massengale Mountain was planted during 1977 and the Rock Springs site on Brushy Mountain was planted in 1978.

The cooperation that the TVA Division of Natural Resources, and Long Pit Mining Co. extended to the University on this project was unending, cordial, and indispensable to the success of the project.

#### Spoil Analysis and Site Characteristics

The mined areas used in this experiment were reclaimed according to the provisions that require surface soil to be replaced as the last layer, rather than mixed within the spoil. Thereby, some quality soil properties existed within the top layer of spoil that would not have occurred otherwise. After the potential plot areas were identified in the field, boundaries were established and spoil samples were taken accordingly.

At each sampling site, the spoil profile was stratified and separate aliquots were taken from the 0-2 cm, 10-15 cm, and 30-35 cm strata for analyses. Sample locations were mapped in relation to plot boundaries

or future references. The Georgia Extension Service analyzed the spoil samples for pH, P, K, Ca, Mn, Zn, and Mg. Available nitrogen was not determined, but it was assumed to be zero.

The site was characterized by two extremes in slope; the larger of the two areas was a flat bench where the coal had been removed from the point of the ridge, but the other area was more typical of the Cumberlands, in that the slopes were steep on either side of the ridge. Sometime after our soil samples were made, the steep slopes were seeded to grass and mulched according to standard, prescribed reclamation procedures. Therefore, two sites of completely different character were available for study. The flat area was not grassed during the study and it has been used for several additional experiments.

Seedling Preparation

Two species of pine were chosen for outplanting; the past success of Virginia pine (Pinus virginiana) in the area was obvious, even though the elevation of the study site (800 m) was slightly greater than the natural range of the species, and pitch pine (Pinus rigida) was chosen due to its reported tolerance of low-quality sites. Seeds of improved stock were provided by Westvaco from their seed orchard near Ivy, VA. Although neither species produces high quality wood, this role was subordinant to that of occupying the site and quickly providing a forest cover for site protection. The second rotation of trees can be managed for other objectives, some of which may have more immediate economic returns.

All seedlings were grown under the direction of U.S. Forest Service personnel in Athens, Georgia. Seeds were sown in flats of one-half sand and one-half peat moss. While the cotyledons were still within the seed coat,

seedlings were transplanted into Hillson-sized rootrainers manufactured by Spencer-Lemaire Ltd, Edmonton, Alberta, Canada. Rootrainers were filled with a mixture of four parts milled pine bark, one part vermiculite, and one part sewage sludge. The medium was then inoculated with a spore infusion of Pisolithus tinctorius. Seedlings were grown for four months in the greenhouse using standard lighting and watering schedules. Liquid fertilizer was applied weekly. About two weeks prior to outplanting, the seedlings were moved to a shade-house to adjust to field conditions from the greenhouse.

Outplanting on Massengale, 1977

The experimental design was a randomized block with four replications in each block of each species as a control and as a minisite treatment. One block was in the grassed area and one block was in the open, flat area. Treatments were assigned as per Table 1.

TABLE 1. VIRGINIA AND PITCH PINES OUTPLANTED ON MINISITE PREPARATION STUDY ON MASSINGALE MOUNTAIN, CAMPBELL CTY., TN June 22 - July 5, 1977.

| Plot No | Treatment | Plot No. | Treatment |
|---|---|---|---|
| 17 | Va - 0 | 33 | Va - 1 |
| 18 | Pt - 0 | 34 | Va - 0 |
| 19 | Pt - 1 | 35 | Pt - 0 |
| 20 | Va - 1 | 36 | Pt - 1 |
| 21 | Va - 1 | 37 | Va - 1 |
| 22 | Pt - 0 | 38 | Pt - 1 |
| 23 | Pt - 1 | 39 | Pt - 0 |
| 24 | Va - 0 | 40 | Va - 0 |
| 25 | Pt - 0 | 41 | Pt - 1 |
| 26 | Va - 1 | 42 | Va - 1 |
| 27 | Va - 0 | 43 | Va - 0 |
| 28 | Pt - 1 | 44 | Pt - 0 |
| 29 | Va - 0 | 45 | Pt - 1 |
| 30 | Pt - 1 | 46 | Va - 0 |
| 31 | Pt - 0 | 47 | Pt - 0 |
| 32 | Va - 1 | 48 | Va - 1 |

The plots were located in the field and each tree planting site was flagged. A tractor-mounted auger was used to drill a 20 cm wide by 60 cm deep hole for each tree of the minisite preparation treatment. The loosened spoil was shoveled from the hole and tumbled in a cement mixer while the amendments were added; nutrients were added on the basis of soil analyses and one-third pine bark was added by volume. Sewage sludge was placed in the hole before the amended spoil was replaced. The tubelings were planted and irrigated once.

Control plots were planted as close to standard outplanting procedure as possible. The spoil was entirely too hard to penetrate with planting bars, therefore heavy iron bars were used to loosen the spoil before planting bars prepared the way for the tubelings. These were also irrigated once. Cognizance should be taken that the same tubelings were used on all plots, the only difference in treatments was the method and extent of site preparation.

The 1977 plots were planted the week of July 1. Although this is well beyond the normal planting period usually considered for favorable results in this area, it was decided to outplant in early summer to test survival and growth of these inoculated tubelings. If planting had occurred when soil moisture was more available and rainfall more likely, irrigation may not have been necessary. We chose to irrigate, due to the normal, anticipated late-summer dryness.

1978 Outplanting on Brushy Mountain

In order to test the procedures used in 1977 and the results obtained from them, the experiments were repeated in largely unmodified design. Two areas on Brushy Mountain were chosen, one grassed and one bare, for

appropriate replications of the same site preparation and pine species treatments that were used in 1977.

Due to its erosive potential, the bare area was scheduled for seeding and mulching during late-summer, only two months after outplanting. Unfortunately, the seedlings were affected by the mulch binding chemical (a latex polymer) and the experiment lost its comparative status with the 1977 experiment. Subsequent mining and remining in the immediate area has also damaged the experiment.

The results stated in this report were generated from the 1977 work on Massengale Mountain.

Analytical Procedures

Survival data were taken in October 1977, March 1978 and October 1978. Some trees were dead but still in situ, others had disappeared (perhaps clipped by an animal), others were alive but obviously affected by the frost-heaving action of a cold winter, and some were alive and growing normally.

In addition to survival, growth statistics were also recorded. Height, diameter at the root collar, and above ground biomass were sampled. All surviving seedlings were measured for height and diameter, and a random sub-sample of two rows from each plot was made for the destructive analyses. Soil samples were taken from the minisite prepared cylinder or from immediately adjacent to the control tubeling in the sub-sample rows.

Projected plans call for more data collection and analyses after five years. The plots will be remeasured and biomass determinations made again at that time. Sufficient trees will be left to adequately cover the mined area. The bare area will be seeded to grass during September 1979, to comply

with federal regulations on mined land reclamation. Growth monitoring will be feasible after that time, but the experiment will effectively terminate with seeding.

## EXPERIMENTAL RESULTS

The technique used to inoculate the growth medium in the rootrainers with Pisolithus tinctorius was not as successful as necessary to insure adequate mycorrhizal infection. Inspection for mycorrhizal short-roots by personnel at the U. S. Forest Service, Institute for Mycorrhizal Research and Development, Athens, GA. revealed less than 25 percent infection, and that was not uniformly distributed throughout the seedlings. Rather some seedlings were adequately infected and others did not show Pisolithus mycorrhizae.

### Tubeling Survival

Survival of outplanted pitch and Virginia pine tubelings is presented in Table 2. Comparisons are possible and desirable with development in time within site preparation treatments and with the initial absence or presence of competing vegetation, i.e., bare sites or grassed sites.

TABLE 2. PITCH AND VIRGINIA PINE SURVIVAL FOLLOWING JUNE OUTPLANTING OF PISOLITHUS TINCTORIUS INOCULATED SEEDLINGS ON STRIP-MINED LANDS IN CAMPBELL CTY., TN.

| Site Cover | Prepared Minisite | | | | Control | | | |
|---|---|---|---|---|---|---|---|---|
| | Survival | | | Frost | Survival | | | Frost |
| | Sept. | Mar. | Sept. | heaved March, '78 | Sept. | Mar. | Sept. | heaved March, '78 |
| | % | % | % | % | % | % | % | % |
| Pitch Pine | | | | | | | | |
| bare | 98 | 93 | 87 | 8 | 95 | 95 | 82 | 69 |
| grassed | 86 | 84 | 77 | 0 | 46 | 41 | 41 | 1 |
| Average | 92 | 88 | 82 | 4 | 70 | 68 | 62 | 35 |
| Virginia Pine | | | | | | | | |
| bare | 98 | 92 | 88 | 6 | 93 | 92 | 83 | 53 |
| grassed | 90 | 81 | 79 | 0 | 61 | 53 | 46 | 4 |
| Average | 94 | 86 | 85 | 3 | 77 | 72 | 64 | 28 |

September, 1977 --

Survival of Virginia pine in September 1977 was better on bare sites than on grassed sites (Table 2). This was true for seedlings planted in prepared minisites as well as for the controls ($p<0.05$). Survival advantage on the bare site was not surprising. Grasses place an extreme demand upon soil moisture, rapidly depleting available moisture following precipitation. Depletion did not occur rapidly on the bare area where native herbaceous cover had not become established.

Survival of pitch pine controls in September was better on bare sites than on grassed areas ($p < 0.05$). This was not true of trees planted in prepared minisites, for there were no statistical differences between grassed and bare sites (Table 2).

There were no statistically significant differences ($p < 0.05$) in September survival rates between minisites and controls for either species on the bare site. Neither were there differences between species, e.g., on prepared minisites; both species had 98 percent survival and pitch pine showed only a 3 percent difference in survival between treatment and control. Sufficient soil moisture was available in bare sites to supply water needs of both species.

Survival of both species in grassed areas was distinctly better ($p < 0.05$) on prepared minisites than on controls. Approximately twice as many pitch pine seedlings died on control plots as died on minisite treatments during the first summer. Virginia pine control survival was 61 percent in the grassed area while the minisite treatment had 89 percent survival. Even though grasses were "scalped" from the planting spots before control seedlings were planted, the grasses recovered rapidly and they soon overtopped the pine seedlings. The combination of shade and water competition was responsible for poor survival of controls.

March, 1978 --

Pitch pine survival was better on minisite plots than for controls on both bare and grassed sites (Table 2). For both sites, seedlings on minisites survived at least 50 percent more than controls.

Virginia pine results were similar and only slightly less dramatic (Table 2). Average survival for both species on both sites showed that

seedlings planted on "minisite" areas had far better survival than seedlings planted without minisite treatment.

Frost heaving was a severe problem for "controls" of both pitch (69 percent) and Virginia pine (53 percent) planted on the bare area, but for minisite plantings frost heaving was less than 9 percent for both species (Table 2). The value of prepared minisites in preventing frost heaving is clear, but the mechanism is not completely understood. Seedlings planted in grassed sites had few frost heaving problems.

More seedlings were missing in "control" plots on the grassed area than elsewhere: 51 percent for pitch pine and 38 percent for Virginia pine. These values exceeded those of all other treatments of Virginia pine by 16 percent and of pitch pine by 39 percent. It was not determined why the seedlings were missing or whether death occurred before they became missing.

Relatively few dead seedlings were found; the highest percentages were 18 percent for pitch pine controls planted in the grassed area. This is a reflection of the severe competition from the abundant grass cover.

September, 1978 --

After two growing seasons, survival percentages of pitch and Virginia pines were still quite acceptable on the minisite prepared treatments with approximately 90 percent alive on the bare area and nearly 80 percent alive on the grassed area. Mortality during the second year was slight.

Survival of the controls on the grassed site had decreased to unacceptable levels, being less than 50 percent. Neither pitch nor Virginia pine showed much ability to compete successfully with the grass, but those still alive were nearly as tall as the grass. Perhaps the grass-tree combination will produce favorable results on spoil stabilization within a few years.

Control trees on the bare area were reported at 82 or 83 percent respectively for pitch and Virginia pine, after 2 growing seasons, but those figures are deceiving in that they include those trees that have frost heaved partially yet remain alive. Their future is unproductive, but they are still alive. Future frost heaving will destroy them.

Tubeling Growth

Survival was the only measurement taken during the first year, at least in part, due to the rather late planting time. At the end of the second season, tree height, stem diameter at the ground-line, and biomass of the tops were measured. Each tree was measured for height and diameter, but a selected sample was selected for the destructive biomass analyses. Growth means are found in Table 3.

Height, 1978 --

There was very little height growth during the first growing season; most of the buds had set during the greenhouse culture and there was no stimulus to resume growth on that harsh site. Most of the height growth during the second year occurred in mid- to late-spring and ceased before the harsh conditions of summer became manifest.

Both pines grew about equally; certainly there were no significant differences between species within the same treatments. On the bare area, prepared minisite treatment, pitch pine averaged 29 cm and Virginia pine was 31 cm tall.

TABLE 3. GROWTH OF PITCH AND VIRGINIA PINES INOCULATED WITH PISOLITHUS TINCTORIUS AFTER TWO GROWING SEASONS ON RECLAIMED STRIP-MINE SPOIL IN CAMPBELL COUNTY, TN.

| Site Cover | Prepared Minisite | | | Control | | |
|---|---|---|---|---|---|---|
| | Height | Root Collar Diameter | Tops Biomass | Height | Root Collar Diameter | Tops Biomass |
| | cm | cm | g | cm | cm | g |
| Pitch pine | | | | | | |
| bare | 29 | .93 | 24 | 23 | .78 | 19 |
| grassed | 37 | .70 | 20 | 28 | .53 | 11 |
| Virginia pine | | | | | | |
| bare | 31 | .89 | 30 | 30 | .86 | 38 |
| grassed | 28 | .48 | 8 | 32 | .57 | 15 |

Pitch pine grew significantly ($p < .05$) better on the bare area when the planting minisite was prepared as described previously, 29 cm tall on the minisite and 23 cm tall on the control. Virginia pine did not respond to minisite treatment on the bare area, with 31 and 30 cm height growth respectively between treatment and control. Even though pitch pine did respond to treatment, it was still about the same size (29 cm) of Virginia pine.

On the grassed area, pitch pine responded to minisite treatment and grew to 37 cm, while the grassed area pitch control was only 28 cm ($p < 0.05$). These were the tallest trees in the experiment and significantly taller than

their pitch pine counterparts on the bare area ($p < 0.05$). This was the only comparison between bare and grassed areas that was significant. The grassed area pitch pine control had attained nearly the same height (28 cm) as the tallest trees on the bare area.

There were no differences in height growth for Virginia pine between treatments on the grassed area. The control was slightly taller than the minisite trees, but not significantly so.

Diameter, 1978 --

Diameter at the ground-line was highly variable, but both species were of the same magnitude, i.e., slightly less than 1 cm. Pitch pine on the minisite bare area was greatest and Virginia pine on the grassed area was the least.

Pitch pine diameters were surprisingly close between minisite treatment and control on the bare area. Although the means on the grassed area were not as close, they were not significantly different at the 5 percent level. There was a significant difference ($p < 0.05$) between pitch pine diameters within the minisite treatment and between the bare and grassed areas. Pitch pine did best on the bare, minisite treatment. There was no difference in the control between bare and grassed areas.

According to its growth response, it didn't matter whether Virginia pine was planted with or without minisite preparation, as long as it was on the bare area. The grassed area treatments produced comparable diameter means within, but they were of less magnitude than pitch pine. Virginia pine diameter on the minisite grassed area averaged 0.48 cm.

Tops Biomass, 1978 --

There were no significant differences in any of the weights of seedling tops, regardless of treatment or area. However, seedlings growing on the

bare area, regardless of species, were slightly heavier. The Virginia pine on the grassed area weighed appreciably less than any other species - treatment combination with means as low as 8g and 15g on minisite prepared and control, respectively.

Analyses were also made of nutrient content of the foliage of selected samples. There were no differences between foliage grown on minisites and the controls for nitrogen, phosphorus, potassium, magnesium, calcium, sodium, and iron.

## DISCUSSION

Perhaps one of the most meaningful realizations is that mid-summer plantings of pines on strip-mine reclaimed sites can be successful, if the site is not grassed and if tubelings are used. When containerized seedlings were first introduced, it was thought that the planting season could be extended beyond the 2 or 3 months normally used. However, to consider planting during the summer months seemed unreasonable. We now believe tree planting on strip-mined sites is feasible during summer months, but some modifications appear warranted, e.g., minimizing the competitive effects of dense grass cover, minimizing the destructive potential of erosion, seedling irrigation, and sufficient spoil amenities to induce good root growth.

We are cognizant that our "bare" site was not realistic. Most, if not all states, require reclaimed lands to be revegetated immediately. If our area had not been experimental, it would have been grassed also.

### Importance of *Pisolithus tinctorius*

There is no question that the presence of mycorrhizae on any root

system is a powerful advantage for survival and growth, so much so in fact that most seedlings can not survive more than a few weeks without the mycorrhizae. Not every mycorrhizal association, however, is equally well suited to provide the greatest advantage to each seedling on each site. Some fungi do well in rich soils like those in the nurseries, but these infected seedlings do not do well on some of the more harsh sites.

Pisolithus tinctorius (Pt) is not a common fungus causing mycorrhizal associations on seedling roots in forest nurseries. Several others are more common, e.g., Telephora terristris, but Pisolithus has shown great advantage to outplanted seedlings on really harsh sites. Numerous studies at the U.S. Forest Service, Institute for Mycorrhizal Research and Development have rather conclusively proven Pt to be superior on seedlings outplanted on reclaimed mine spoil.

Our seedlings were grown with some pioneering techniques of attempting to infect seedling roots with Pt; we dispersed spores across the top of the planted rootrainers and quickly watered them into the media. This was the best technique available within our means, for spores were readily accessible. Pure cultures of mycelium were not available to us at that time. Our success with spore inoculation was low and extremely variable. Other researchers have experienced similar frustration.

Instead of equipping our tubelings with a powerful advantage on harsh sites, we created an uncontrolled variable within the experiment because most of the seedlings failed to become infected with Pisolithus. It was evident in the field that some seedlings were infected and others were not; the infected seedlings were biggest, had a dard-green, well-developed foliage.

These seedlings were not numerous enough on the plots to manifest themselves in the analyses except as a source of variability. Better techniques for inoculating tubeling roots are now available for use by commercial nursery growers through commercially prepared inoculum from Abbott Laboratories.

Some U.S. Forest Service plots immediately adjacent to our plots contained seedlings with a high proportion of roots infected with Pt. These tubelings were inoculated with mycelial cultures in the rootrainer before outplanting. Their growth has been superior in all respects to our trees. The non-inoculated controls on the Forest Service experiment were more comparable to our seedlings.

No seedling that would otherwise form ectomycorrhizae should ever be planted on strip-mine spoil without Pisolithus. The techniques are now available to grow infected seedlings by the millions.

Survival and Growth

The effects of grass competition upon newly-planted pine tubelings were demonstrated conclusively during the first growing season of this study. Very few of the seedlings remaining alive on the grassed plots were free-to-grow above the grass competition. If seedling height growth is not sufficient to quickly establish the pines above the shade effects of the grass, the trends of the first year will be further exaggerated, perhaps to the extent of eliminating the pine from the site. Survival the second year decreased slightly across all treatments, without the grassed area being affected more than the bare area.

The two species responded differently to the grass competition. Virginia pine was least able to cope with the grass, for it showed the lowest

survival and growth of all combinations. Perhaps this reflects the strong pioneer successional role that Virginia pine fulfills in so many ecosystems. In order to outplant this species and satisfy reclamation regulations, it may be necessary to reduce the amount of seed in the seed-mulch mix.

It would appear possible and desirable to seed the grass cover at a lower rate, thereby allowing tree seedling establishment and some height growth before the grass cover becomes extremely dense. All but the most steep slopes could be seeded in this way. If it is necessary to plant on grassed sites, it would be desirable to kill the grasses and other vegetation in a circle 45 to 60 cm in diameter with a biodegradable herbicide several weeks prior to planting.

Pitch pine responded differently than Virginia pine. This species is better able to grow with some cover, in fact, it did best on the minisite prepared, grassed area. Without some type of amelioration action, pitch pine did not do well on harsh sites in this study. Perhaps pitch pine would be a better species to outplant on those grassed sites than Virginia pine. The grass cover plus some local site amelioration produced an environment for the tallest pitch pine seedlings after two years.

All seedlings in this experiment were irrigated one time immediately after they were planted. A heavy rain during the first night after planting may have made irrigation unnecessary. It is still reasonable that summer plantings need at least one thorough watering to assist root establishment and growth.

Without irrigation, survival would be unacceptably low in areas with summer dry periods. During this experiment, August was typically dry but seedling survival remained high. Water-stress measurements were not made.

The reclaimed spoil in this experiment was not too unfavorable for plant growth. Potassium and phosphorus were acceptable and pH was only moderately acid. There was a scarcity of nitrogen and organic matter and some hotspots became apparent after a few months.

Perhaps the greatest amelioration factor used in this work was the organic matter that was mixed with the spoil and fertilizers. Milled pine bark was used to provide some spoil structure, increase aeration in the root zone, increase percolation rate for rainfall, and to facilitate root growth out of the rootrainer media.

From a practical standpoint, it would be desirable to use slow-release fertilizer pellets with a complete spoil amendment. This would preclude the necessity for making detailed soil analyses to determine mineral deficiencies. Nitrogen additions should not be too great, so as to interfere with mycorrhizal infection and root establishment. Spoil pH would determine the amount of lime to be added to the root zone.

Costs

Cost figures on this research are somewhat unrealistic for operations planning, for all the obvious reasons. In addition to the two faculty and two graduate research assistants, a total of 352 man hours were hired at the minimum wage of $2.65. Seven days were spent on the site during 1977, plus one tractor for eight hours. The materials used in site amelioration were not extensive and were purchased for less than $50.

Records were not kept on the cost of raising the tubelings in the greenhouse, since they were grown under supervision of the U. S. Forest Service at Athens, GA.

Plantings in 1978, although not as extensive as those in 1977, were accomplished with one long day in the field. Tractor work was contracted

for $80, and only 50 man hours at $2.90 were used. The costs of land preparation for the experimental area are given in Table 4.

An operational study on a larger scale would be necessary to more fully evaluate and account for costs. Logic would indicate that costs would be less than area-wide amelioration but our system is more labor intensive.

TABLE 4. COSTS OF LAND PREPARATION AND MINISITE DEVELOPMENT (ON A RECLAIMED SITE OF 3.5 ACRES) 1/

| | Initial Preparation 1977 $ | Completion of Preparation 1978 $ | Total Costs 2/ $ |
|---|---|---|---|
| Labor (at minimum wage) | 933. | 145 | 1078. |
| Tractor hire (wheel type) | 80. | 80 | 160. |
| Materials | 50. | 50 | 100. |
| Total | 1063. | 275 | 1338. |

1/ The experimental spacing of minisites was 3' x 6' which is at least twice as dense as normal reclamation plantings.

2/ On rougher sites a track-type tractor would be required for land preparation with higher costs for tractor hire.